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STOCK-WATERING PLACES ON WESTERN GRAZING LANDS.

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CONTENTS.

NEED FOR WATER ON THE RANGE.

On many areas throughout the Western range country the water supply is not sufficient for the number of stock the forage will support so that the lands must be understocked in order to use them at all. On other areas the water supply is sufficient for all the stock the range will carry, but is not permanent, and the animals must therefore be removed before the season is over. Still other areas are made practically worthless for stock purposes by the absence of water except at rare intervals during the winter, when the presence of snow allows their temporary use.

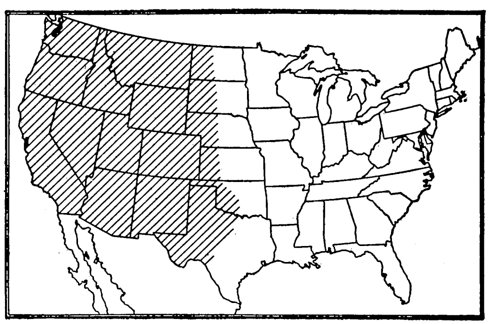

Fig. 1.—Map showing section of United States to which this bulletin is applicable.

The natural growth of the stock industry makes it imperative that all grazing lands should be brought to a condition where they can be utilized to their full capacity. No stock range can be properly utilized if there is an uneven distribution of water.

Note.—This bulletin gives suggestions for the development and improvement of stock-watering places; it deals more especially with conditions found within the National Forests. It is intended for distribution throughout the range country.

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The suggestions given in this bulletin for improving the water supply on grazing areas in the West are the result of the experience of the Forest Service in adding to or developing the water supply upon grazing areas on the National Forests, where the aim is to open up all new and heretofore practically unused range, to utilize more completely the forage on ranges now in use, and to insure a better control of the ranges themselves. In all, a total of 676 separate water improvement projects have been developed within the National Forests; 329 by the users of the range themselves, 172 through cooperation between the Service and the users, and 175 by the Forest Service alone. Of these 676 improvements, 378 are springs or seeps, 286 are reservoirs or tanks, while the rest are wells, trails, and the like.

DAILY WATER REQUIREMENTS OF LIVE STOCK.

The first point to be considered in developing the water resources on grazing areas is the amount of water necessary for individual animals of each class to be grazed. Unfortunately, no records have been kept or studies made of the requirements of stock grazing on the open range. However, it is known what amount of water is consumed by nonrange stock fed under ordinary farm conditions. Observations of the amount of water consumed by horses under varying conditions of work and weather indicate a daily consumption of between 50 and 110 pounds, or from 6 to 13 gallons. A pair of mules at the Oklahoma State Experiment Station drank, during hot weather, 113 pounds (13.6 gallons) per head daily, while one day they drank 175 pounds each.[1] Prof. Henry, in his work, "Feeds and Feeding," says: "In Germany a full-grown ox placed in a respiration chamber drank 123.7 pounds (14.9 gallons) of water in 24 hours." At the Pennsylvania State Experiment Station cows fed fresh grass consumed 60 pounds (7.2 gallons) each per day, while others fed dry grass drank 107 pounds (13 gallons) per day. The New York State Experiment Station found that dry cows drank 65 per cent as much as cows giving milk. Sheep on feed in Colorado consumed approximately 5 pounds of water (2.5 quarts) per head per day. In Michigan, on almost the same class of feed, grain and hay, sheep consumed from 1.4 to 2.8 pounds of water per day. Prof. Henry says: "A sheep needs from 1 to 6 quarts of water daily, according to feed and weather." Forest officers estimate the average daily demand for water by the several classes of stock using National Forest range to be from 8 to 10 gallons for cattle, and from 0.5 to 2 gallons for sheep. In providing for a water supply for the different classes of stock, it will be fairly safe to estimate, therefore, not less than 10 gallons per head per day for cattle and horses, and 1½ gallons per day for sheep. Naturally this amount will vary with the season,

[1] Farmers' Bulletin 170, Principles of Horse Feeding, p. 26.

and with the condition of the feed, whether green and lush or burnt and dry.

When the feed is very fresh and the morning dews are heavy, the herd will often go for comparatively long periods without needing water other than that secured from their food. Under such conditions herders in the high mountain meadows usually do not take their bands to water more often than once in every 8 or 10 days, if the supply is some distance away. Cattle, on the same class of feed and under similar conditions, will also need less water than ordinarily.

RELATION OF WATER SUPPLY TO FOOD PRODUCTION.

Sufficient water at all times is absolutely necessary to enable stock to reach a marketable condition. However strong or plentiful the grass and forage on a given area may be, the animals using it must have all the water they need or they will not thrive.

It may be taken as a fact that a full and easily reached supply of water is quite as necessary to range stock as a supply of grass and forage. They can not be fattened and turned off in a marketable form without both, but if it is merely a question of living through the year, regardless of fitting them for market, a short grass supply is less likely to result in disaster than is lack of water.

WARM AND COLD WATER.

Prof. Henry[1] finds that, since the temperature of the water taken into the body must be raised to the temperature of the body, animals exposed to cold, especially those in poor condition, will be benefited by drinking warm water. In this connection, the writer for several years carefully observed a large number of cattle which watered regularly at a windmill in New Mexico. Though in winter large openings were cut in the ice on the overflow pond, where the cattle generally watered in summer, so that the water along the sides was entirely clear and easily reached, the cattle would invariably go to the troughs at the mill, which were free from ice and where the water was comparatively warm. In range improvement, therefore, the advantage of warm over cold water should be taken into account.

DISTANCE RANGE STOCK SHOULD TRAVEL TO WATER.

Another thing to consider in locating watering places is the nature of the country over which the stock must travel to reach them. Cattle and horses will go long distances for water downhill in preference to going comparatively short distances uphill. They will also go long distances to water on smooth, fairly level ground in preference to going short distances down some steep, rocky canyon or mountain

[1] Feeds and Feeding, p. 64.

side. Though cattle and horses dislike to go down a steep hill, they will feed up one very readily. It is an old range saying that a small boy can drive 500 head of cattle up a mountain side, though it would require a dozen men and some hard work to drive them down.

Observations on the National Forests indicate that on average ranges cattle should not be required to go more than 2 miles to reach water, if they are expected to be in marketable condition in the fall. Under the most favorable conditions, however, they may travel as much as 4 miles, though in extremely rough, mountainous country the maximum distance should be nearer half a mile.

NATURAL WATERING PLACES AND THEIR IMPROVEMENT.

SPRINGS.

Throughout the West the words "spring" and "seep" are very generally used to designate one particular source of water supply. By spring is meant a natural outpouring of subterranean waters which find their way to the surface through some crevice in the earth, with a fairly steady flow sufficient for stock-watering purposes. A seep, on the other hand, has a very small or intermittent flow, and often forms merely a wet place on the side of some hill or in some open spot. The flow from ordinary springs can be increased by comparatively simple means, and even seeps may be developed and made a source of water supply for a considerable number of live stock.

The work of cleaning out and improving a spring may be done in several ways. If the flow of water is so rapid as to hinder digging, and bailing will not do, a small hand pump may be used to keep down the flow. An ordinary iron pitcher pump on a 1½ or 2 inch pipe will handle a large amount of water at the expenditure of very little labor. Where one of these is not available, a homemade pump may be constructed from a 4 or 5 inch galvanized-iron tube of sufficient length, with the necessary overflow spout. A homemade valve with a straight wooden pole handle, worked either by hand or by a pump handle, will cost little, and will raise a maximum amount of dirty and muddy water with a minimum of power.

When the water is disposed of the ground about the spring should be dug out. To determine how deep to make the excavation, take a long pole, or preferably an iron rod ⅜ or ½ inch in diameter, such as every village blacksmith has on hand, sharpen the point, and work down as a sounder. If the rod is not long enough, cut a thread on the ends of two pieces and join them with the common coupling used for iron pump rods. In deciding how deep to dig it should be borne in mind that the closer to bedrock the curbing goes, the stronger and steadier will be the flow. In few springs does the flow come from a single opening, but when the spring is clear it is easy to discover the several small holes through which the water finds its way out of the ground.

Curbing.—Wood is the poorest material for curbing springs; cement the best. Though wood submerged in water will last a reasonably long time, that part of the curbing above the permanent water line must be renewed at least every 5 or 6 years. Stone and rock are better than wood and are usually available. They make a substantial and lasting wall at a minimum cost. Wherever possible stone should be laid in cement to keep out surface waters from the spring.

Of all curbing materials, cement is the most permanent and costs least for repairs and upkeep. Cement curbing may be constructed in the ordinary way with forms, and reinforced with wire or other material, or it may be built of blocks. Blocks are by far the best, since they may be molded in accordance with the shape of the excavation so as to key into one another and form a perfectly solid wall which will resist tremendous pressure from the sides.

The amount of material needed for cement curbing is small, and may often cost not much more than lumber. Cement is now regularly carried in stock by dealers in almost every small town, and the sand and broken rock needed can nearly always be secured in the neighborhood of the spring.

Walls built on the surface.—Sometimes the earth about the spring is badly cut or damaged by stock, or the spring may lie in the middle of some bog hole or swamp. In such cases the sides of the excavation are not likely to stand up during the process of digging. Often, too, quicksand will run in faster than it can be removed. When one of these conditions presents itself, it has been found advisable in building the curbing wall to make a flat foundation frame of 2 or 3 inch plank the size of the excavation and a few inches wider than the width of the proposed wall. This is laid on the ground around the spring, and the walls, whether of stone, cement, or cement blocks, built upon it. The weight of the material upon the frame will force the latter down as the earth and sand are removed from under it, and with a little care the work of erecting the wall can be carried on above ground while the frame slowly settles down into the spring. If cement is used the forms can be set upon the frame and built up foot by foot as it sinks. When the work is finished and the cement properly hardened, the forms inside of the wall can be torn out and those behind allowed to remain. This foundation-frame method will also be found convenient in building a rough wall of stone or rock, since the stones can be better matched and fitted together when the work is done above ground. Moreover, if it is not convenient to excavate entirely down to bedrock or solid earth, the frame furnishes a base which in most cases prevents any further settlement of the wall. Even if the wall should settle, it would do so evenly, and could be built up again on top without in the least disturbing the substructure.

Raising the level of a spring.—Sometimes it is desirable to raise the level of a spring so that the water can be more easily carried to the troughs. This can be done during the course of the general improvement work if the origin or head of the spring is high enough above the outlet, and the surrounding earth sufficiently firm to stand the necessary pressure. To determine these facts place a section of iron pipe, large enough to carry off the flow and with plenty of additional room to provide for its becoming partly clogged by substances of any kind, in the retaining wall when the latter is built up to the height to which the water has always risen. Then, when the wall is built up 6 inches farther, place in it another pipe similar to the first. Then drive into the lower pipe a wooden plug and see if the water will rise to the next outlet. Before closing the first pipe measure the flow of the spring by observing how long it takes to fill a vessel of known capacity, and do the same thing after the pipe has been closed, in order to see whether in the raising process there has been any loss of flow. Experience has shown that if the flow is decreased more than 50 per cent it is better not to attempt to raise the spring. If the spring loses nothing by the additional raise in its outlet, however, the process can be continued by putting in new outlets and closing the lower ones until the water has been forced to rise to the desired height.

Should the flow cease or refuse to rise to the new height during the tests with the first or second pipes, it may be because the water has broken out at some other point. This is especially likely to occur when the spring is in a soft spot, such as a swamp or bog hole. If after an examination in the vicinity of the spring this is found to be the case, the ground about the spring may be loaded sufficiently to stop the leaking. A solid corduroy floor of logs should first be laid about the spring and extended outward as far as practicable and then weighted down with rock. The more rock used, of course, the better it will be. When the floor has settled as far as it seems likely to do, a top covering of dirt should be put on to make a good footing around the spring. The strength of the spring should then be tested again, but no attempt should be made to force the water higher until the corduroy floor has had plenty of time to settle down and stop the outside leakage. After a few months, however, additional pipe openings may be placed in the wall if there is need for raising the flow further. One instance is known where the water in a spring was raised 2 feet by this method. However, there is a certain element of chance in this raising process through the possibility of losing the flow which the person handling a project must carefully consider before beginning operations. If the water finds another channel too far back from the spring, the flow can not be recovered through corduroy work as described above.

Location of troughs.—Once the need for improving a spring has been settled, the next step is to locate the spot where the watering troughs should be placed. On the Kaibab National Forest, Ariz., water has been piped out from rough canyons over a distance of more than 2½ miles, and in several other cases for more than 1,000 feet. In each instance, however, the additional amount of range gained and the very rough nature of the country immediately about the springs justified the expense. Ordinarily it will not be profitable to pipe water any such distances. On a large number of water improvements within National Forests the average length of pipe between the spring and the troughs is approximately 33 feet; on the majority of improvements the average distance is seldom more than 25 feet. However, if placing the trough some distance from the spring will save stock much travel up and down a very rocky trail, or even a half mile up some sandy wash, it may well be considered whether the saving to the animals will not justify the additional expense.

The trough should be located on ground with sufficient drainage to carry off the waste and surface water and sufficiently below the outlet of the spring to insure a fall which will enable the water to sweep before it any moderate amount of foreign matter that may find its way into the pipe. It is a mistake to use pipes with a diameter less than 1 inch, though the more nearly the flow fills the pipe the better it will be. The matter of laying the pipe under or above ground is one to be settled by local conditions. If there is no road or trail to be crossed, and if the elevation between the trough and the spring does not call for lowering the pipe at any point, it will probably not be necessary to bury the pipe or otherwise cover it, provided the water comes directly from the spring at the usual temperature. If the pipe is likely to be disturbed in any way, however, it is better to place it a few inches below the surface. Usually in joining the pipes together it is better to have "unions" at regular intervals for convenience in examining the pipes for possible obstructions. A long telegraph wire of about No. 8 size, with a sharp barbed point on the end, will furnish the most convenient means of cleaning out a pipe, up which it can be pushed for 50 or 75 feet.

Fencing a spring.—It is always advisable to protect a spring by a stout fence of poles, logs, or wire, whichever is cheapest. This prevents the stock from watering at the spring itself, falling into it, or breaking down the walls and affecting the flow. If wire is used it should be well stretched and the corner posts firmly braced. Excellent protection for a spring is a small log crib built up about it to a moderate height. If the logs are peeled and placed on good foundation stones at the corners, such a crib will last many years.

Fish in springs.—It is quite commonly believed that the presence of fish tends almost wholly to eliminate the growth of vegetable

matter in the pipe leading to the troughs, which interferes with the flow of most springs. In Arizona, 8 or 10 trout were placed in a large spring which had been cleaned out and cemented up. They lived there for over 10 years, during which time the spring was exceptionally free from all vegetable growth, though another spring near by, which contained no fish, was continually full of such growth, making it necessary to clean out the pipes at frequent intervals. Both springs were practically alike as far as the nature of the water and surrounding conditions were concerned.

SEEPS.

Seeps may be improved in much the same manner as springs. Since their flow, however, is much smaller than that of the average spring, it is generally necessary to dig them out enough to secure every drop of water they are capable of yielding. This may be done through open cuts running across the wet spot where it is in an open place, or by "drifting" into the side of a hill where the water shows its presence. Often a mere drip of water from some seam in a ledge can be developed into a much larger supply by merely drilling a hole 6 or 8 feet into the rock close to the "seepy" place and "springing" it with a charge of black powder. Seep development is a good deal of a gamble, and if the work bids fair to be expensive it must be justified by the necessity for more water on the range.

There is usually greater necessity for storing the flow of a seep than of a spring, since in the case of the former advantage must be taken of the flow both day and night if sufficient water is to be secured for the stock. A stream from a seep not larger than a lead pencil will, if properly saved and reservoired, furnish water for a very considerable number of stock. In estimating the probable size of a storage tank or reservoir, the flow of the seep may be ascertained by the methods described on page 6.

SWAMPS.

Swampy spots, lying somewhat lower than the surrounding country, can often be made to furnish a water supply sufficient for a number of stock. Thus, on the Fremont Forest in Oregon, a spring in the middle of a swamp was cleaned out and an open channel cut across the swamp far enough to allow the flow to run down the draw below into a series of large open pools. This channel collected the surface and spring water, which before had been of little use, and supplied it to a band of sheep. By cross cutting such spots and accumulating the water at a central pool, from which it can be carried to some reservoir or catchment basin through open ditches, the supply will be increased considerably. Water development in swamps not only increases the supply, but often removes a dangerous and annoying bog hole.

TRAILS TO INACCESSIBLE WATERS.

Western streams often flow for many miles through deep canyons, while near by are excellent stock ranges unused because of lack of water. Such streams may frequently be brought into use by the construction of trails, by means of which the stock may reach them, or by lifting their waters to the surface. On a National Forest in northeastern Arizona stockmen have built many first-class trails down the side of a canyon whose walls are almost perpendicular. The most successful of these trails are built with wide and comparatively level landings at the turns or switchbacks, so that the stock can conveniently pass each other or even rest there if they feel inclined. Many of the trails are blasted from the solid rock with outside walls built up by means of a retaining log held in place by steel rods set in drill holes in the rock and secured by cement or some similar material. To prevent the washing of the soil put on the rocks to furnish a footing for the stock, logs are placed across the trail at intervals, making it possible to level up the spaces between them and so form a series of easy steps. Where overhanging or jutting rocks endanger pack animals or riders, they are blasted away. On one Forest in Arizona several sheep trails have been in use for many years in a canyon whose walls are between 500 and 600 feet high. Bands of ewes and lambs, numbering as many as 1,500 head of old stock, have passed up and down them for long periods with no loss except an occasional animal stampeded through some cause or other.

In using trails of this kind, the stock, especially sheep and cattle, should never be crowded. Animals like to take their time going down such places, and if crowded they will bunch up on the most dangerous points, which may result in injury and possibly death to some of them.

Some of the means of raising water to the surface of a canyon by machinery are described on pages 7 and 8.

ARTIFICIAL WATERING PLACES.

One of the very first methods of adding to or improving the water supply was to increase the capacity of the many prairie lakes and reservoirs scattered about on the ranges. This generally took the form of providing a more ready way for water to reach the lake, which was done by plowing furrows diagonally across the slopes leading down to it and so guiding the flood waters directly to a central point. In this way the precipitation from many small storms, which otherwise would not have reached the lake, was gathered up and stored for use. Again it was found possible by building small diversion dams to bring to the natural lakes or reservoirs the flow from distant "washes" or dry "arroyos" during the rainy season or while the snow was melting. Such ditches often carried the water for many miles around hillsides, and in some cases high flumes were built across deep valleys.

Later, when the demands upon the range became greater, the natural reservoirs were supplemented by artificial ones. Experience soon brought out the fact that the mere damming up of a stream would seldom serve the purpose, since the silt and débris quickly filled up the reservoir behind the dam, turning it into merely a dangerous bog hole where weak cattle found their final resting place. But by locating the reservoir in some adobe flat and leading the water to it through a ditch, very satisfactory results were obtained. Thus to-day one of the most important means of adding to the supply of water on certain forest ranges is through flood-water reservoirs.

RESERVOIRS.

Where a natural water supply is more than 1 mile distant, there seems to be no reason why small reservoirs can not be built upon almost every section in the open park-like places found on most Forests. Such reservoirs, which are usually auxiliary or supplemental to the natural water supply, need not cost much to build or maintain. If a low place is selected in the middle of some open park with sloping hills about it, comparatively little work with plow and scraper will construct a reservoir which, when trampled and puddled by use, will hold water sufficient for many head of stock for some time. Furrows running diagonally across the slopes will collect the rainfall or melting snow waters and carry them directly to the reservoir for storage. Artificial reservoirs permit the stock to be scattered out over a larger area than ordinarily and remove the need for them to concentrate at permanent watering places. It is remarkable how quickly stock, especially cattle, will find these new supplies of water and utilize them. Even though such a supply does not last for more than a few weeks, or even days, it will in a very short time well repay the cost of obtaining it.

Two methods are followed in constructing dirt reservoirs. The first is to dig out the ground in some open adobe flat and build up the walls with the earth taken from the excavation. The second is to select some dry wash or canyon where it narrows down to a reasonable width and inclose it with a dam of earth. The last method insures the greater storage capacity and is the one most commonly used in the West. Its drawbacks are (1) the dangers from unusual floods, which may sweep down the wash and in a few minutes overwhelm the waste gate or spillway and tear a hole through the dam; and (2) the practical certainty that silt will find its way into the reservoir and gradually fill it up. With regard to this last objection, however, the silting-up process may be made less rapid by constructing a small "settling" basin with "flashboards" a short distance above the reservoir itself.

Before work begins on any type of reservoir three matters should be settled which have an important bearing upon the choice of a site. These are (1) the gallon capacity of the reservoir, (2) the amount of water the animals will require each day, and (3) the natural loss from evaporation and filtration. Knowing the dimensions in feet of the proposed reservoir, and estimating that each cubic foot of water contains $7\frac{1}{2}$ gallons, the gallon capacity can easily enough be figured out. Data on the daily water consumption of the various classes of live stock are given on page 2 and on evaporation and filtration losses on page 15.

Soil requirements.—A heavy adobe or clay soil is one of the first requisites for a reservoir site. If this is found, the question of leakage

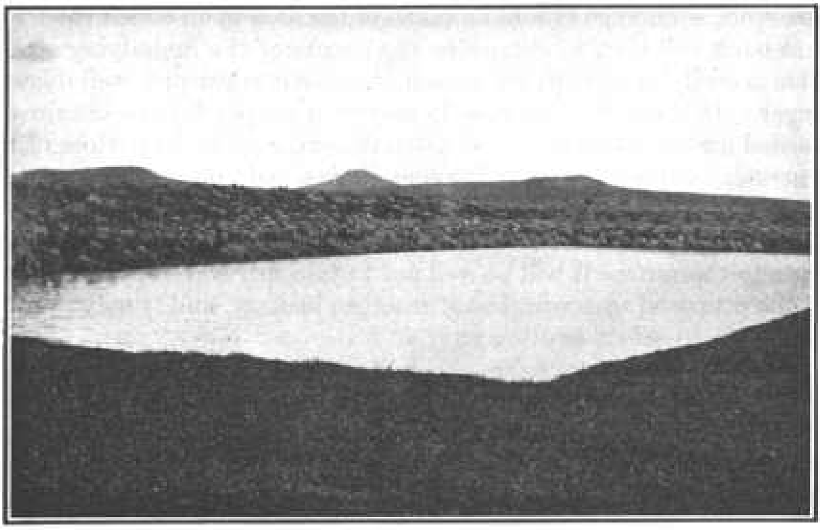

FIG. 2.—An earth reservoir for impounding flood waters used for sheep-watering purposes, Coconino National Forest, Ariz.

is not serious after the first filling. The passing back and forth over the work by the horses as the reservoir is being built does much to settle the banks, though generally additional means must be employed. The usual plan is to place salt on the banks and in the bottom of the reservoir. This attracts the stock, which soon trample down the material used until it is almost impervious to water. Good results have also been obtained by taking a band of range or other horses, and, with a foot or two of water in the bottom of the reservoir, running them about in it for an hour or so. Several hundred head of range cattle held in the tank for a few hours will give the same results. Sheep may be used, but the process is a hard one on both animals and wool.

Where the soil lacks in clay or adobe qualities, excellent results have been secured by hauling clay from some near-by place and scattering it over the bottom and sides of the reservoir. By the means just described this can be worked into the soil so thoroughly as to make the tank water-tight.

Several experiments to stop reservoirs from leaking by running a trench 3 to 5 feet wide on the lower side of the embankment and down to bedrock, filling it in with clay, have not given very satisfactory results. In every case the leakage continued, probably because it was through the bottom of the reservoir and not through the bank. In most cases, placing from 2 to 4 inches of good stiff clay on the bottom, and seeing that it was well puddled, stopped the leak.

Testing the ground.—Before finally deciding upon the location of a reservoir, soundings should be taken of the area upon which the water and bank will rest, to determine the nature of the underlying strata. This is easily done with a common fence-post auger or a well-digger's auger. If the soil is shallow it may not be possible to obtain the needed material for the banks without endangering the bottom of the reservoir, and in such cases the soundings should be continued until a spot is found where plenty of soil can be obtained for the banks without going too close to bedrock. If loose rock or gravel is discovered close to the surface it will be well not to take any soil from the bottom of the proposed reservoir, lest it result in leakage, and it may even be advisable to select another site.

Building the embankment.—In building the embankment of a dirt reservoir the first step is to run an open ditch for its entire length in the center of the base on which the embankment will rest. This ditch, which should usually not be less than 2 feet wide and 3 feet deep (wider if the base width of the dam is greater than the average, but of course not as deep if bedrock is close), is meant to be filled up with dirt taken from the excavation. In this way the embankment is keyed into the ground, and neither slides nor water can find their way between the new work and the more solid ground on which it rests.

Soil for the embankment should be dug from the site of the proposed reservoir in a long, narrow pit. This increases the capacity of the reservoir just so much, and will furnish a depression in which the water will gather as the amount shrinks, thus permitting the stock to obtain practically every gallon there is in the tank. It tends, too, to reduce the lose from evaporation, since the water, as it lowers, is concentrated in a single deep hole instead of being scattered over the entire floor of the reservoir in a shallow sheet.

Embankments are often built with a core of logs and brush, over which the earth is dumped. Sooner or later, however, the logs and brush must decay, bringing about a depression in the embankment

and a general loosening up of the earth sure to result in leaks and possibly serious damage to the whole structure.

No embankment should be considered finished until its upper face, from the bottom level to the crest, is riprapped with rock large enough to insure its remaining in place under trying conditions. If the riprap work can be carried up as the embankment is built, keeping a little ahead of the earth, it will do much to prevent the borrow pit from filling up with waste dirt from the face of the bank.

One of the best means of protecting the bank against erosion by waves due to high winds is to run a double boom of logs clear across the face of the dam just at the water line. The logs should be fastened together in pairs by heavy wire, and each end of the boom chained to a stout post placed in the earth at the end of the embankment. The boom then lies upon the riprap work just at the water line, and floats freely, acting as a break against which the waves lose their force.

Covering the face of the embankment with brush held in place by stakes is a cheap though temporary means of protection. If it were not for the likelihood of its being displaced by stock running over it, or destroyed by fire, it might be relied upon for permanent use.

Spillways.—No matter how well built a dam may be, if sufficient allowance is not made for carrying off any excess of water, a part or perhaps all of the embankment is certain to be swept away. The large majority of dam and reservoir failures may be attributed to some defect in the spillway. The most common is that the spillway is too small for the body of water which may sometimes come sweeping down the canyon or valley into the reservoir, with a head of perhaps 4 or 5 feet. The reservoir fills to the brim, a tiny rivulet cuts its way across the top of the dirt fill, and in a few minutes there is a wide gap in the embankment through which probably every drop of water in the reservoir runs out. In such cases repairs may cost almost as much as the original work, while in the drier regions it may be a year or two before another flood occurs of sufficient size to fill the reservoir again.

Another instance in which spillways fail is when, through faulty construction, the water finds its way beneath the spillway floor, or, if it has no floor, tears away the riprap work which lines it, and cuts into the embankment until the reservoir is ruined.

A third danger lies in locating the spillway at too high a level. In such cases the water, before being able to run out, may rise so close to the top of the embankment that on a windy day waves may be whipped across the crest of the dam, on which there may be a low spot through which the water readily finds passage. Experience has shown that the water should never be allowed to rise closer than

2 feet of the top of the embankment before it begins to run out of the spillway.

Having figured out as closely as possible the spillway room necessary to carry off the surplus water from the reservoir, it is far better to err on the safe side and perhaps double the figures than to build on too small a scale and some day see the entire work torn out as a result of some cloudburst.

Care must be taken so to divert the waste water as it comes from the spillway that its eddying force does not cut into the toe of the embankment and undermine it. This can usually be done by placing plenty of riprap work or loose rock along the sides of the embankment below the spillway.

The ideal wasteway is one so located that when the water in the reservoir has reached its proper level the supply will overflow either at some point before it enters the reservoir or at the extreme rear of the latter, where it can be led over some rocky ledge or low place in the surrounding ridge. If the reservoir is filled from a ditch a waste gate at the proper level in the ditch bank will serve the purpose. Should this be undermined by the water no great harm will be done, for the cut made in the bank could drain off but a small amount of water from the reservoir proper.

Fencing.—As a general thing a reservoir embankment is saved a great deal of wear and tear by fencing it in. If stock are allowed to run over it as they please, trails will be worn here and there, which may offer fine opportunities for some accidental overflow. Trampling by stock also cuts down the banks to a considerable extent and narrows the width of the top of the fill so that much of its strength is lost. The usual plan is to run a wire fence clear around the dam or embankment, both inside and out, so that stock can not get on it at all. Where the bank is riprapped the fence need only come down to the top of the riprap work.

Usually stock are allowed to enter a reservoir to drink, but where, as sometimes happens, the water is also needed for domestic purposes it is necessary to keep them out. In such cases a string of troughs is constructed below the reservoir to which the water is drawn through a pipe controlled by a float valve, thus keeping the troughs full at all times.

Cost.—The cost of building a reservoir of the character described is not excessive. The material need usually be moved only a short distance, and a considerable amount can be piled up in a day with the ordinary "slip" scraper. As the bank rises, either a wheel scraper or the type known as the fresno should be employed. Such work, under contract, should not cost over 20 cents per cubic yard, and if the amount to be done is large and the earth close at hand it should cost even less. Figuring the cost of a team and driver

at $3.50 per day of 10 hours, and other labor at $1 per day, the following will be the approximate cost of moving earth for an ordinary reservoir embankment:

Amount of earth moved per day.

Haulage.	With slip scraper holding ¼ cubic yard.	Cost.	With wheel scraper holding ½ cubic yard	Cost.
Feet.	*Cubic yards.*	*Cents.*	*Cubic yards.*	*Cents.*
50	60	9.0-11.0	100	6.6- 9.1
100	45	10.9-13.4	90	7.0- 9.5
200	30	14.9-17.4	60	9.1-11.6

The cost depends largely upon the nature of the soil, heavy soil requiring more plowing and loosening up to facilitate loading it on the scraper.

The average actual cost of 8 reservoirs on the Lincoln National Forest, with an average capacity of 1,250,000 gallons, was $506; of 6 reservoirs on the Prescott National Forest, with an average capacity of 216,000 gallons, $183; of 5 reservoirs on the Prescott National Forest, with an average capacity of 300,000 gallons, $340; and of 7 reservoirs on the Tusayan National Forest, with an average capacity of 473,000 gallons, $247.

Loss by evaporation and filtration.—When a reservoir is fairly well settled and the leakage is reduced to a minimum, the daily loss of water through evaporation and filtration, or soaking into the earth, will not exceed from a half to 1 inch. In new reservoirs, however, it will be considerably greater.[1] The loss by evaporation is greatest during the three summer months, but takes place at all seasons of the year. At the Roosevelt Dam in southern Arizona the actual loss of water by evaporation approximated 6 feet per year. With the average stock-watering reservoir in the West, where evaporation is at the maximum, probably as much water is lost through evaporation and leakage as is taken from the reservoirs by the animals themselves. With the figures given, however, and a knowledge of the number of stock that will water at the reservoir it should be possible to determine pretty accurately the demands that a reservoir will be called upon to meet.

WELLS.

In comparatively few places throughout the West can well water be obtained at moderate depths. The cost of drilling a well with modern machinery, however, is not great, and where water is more than 50 feet below the surface the best way to reach it is by drilling or boring. Up to a depth of 500 feet the average cost of a well where work is done under contract is approximately $1 per running

[1] Civil Engineers' Handbook, Trautwine.

foot. This does not include casing, which will cost $1 per running foot if of steel or heavy iron, and 25 cents if of galvanized iron, making the total cost per foot between $1.25 and $2. Where the hole is in rock, casing may not be necessary.

In many parts of the West the charge for digging open wells down to 50 feet is about $2 per foot, which includes sawing and setting the curbing in place, if lumber is used, but not the cost of the material. Lumber should never be used for curbing, because of its rapid decay. Here again, as in the case of springs, cement blocks are the best for the purpose. Whether these or ordinary rough stones are used, the same system of preventing dangerous slides can be employed as is recommended for springs; namely, to build the walls upon a

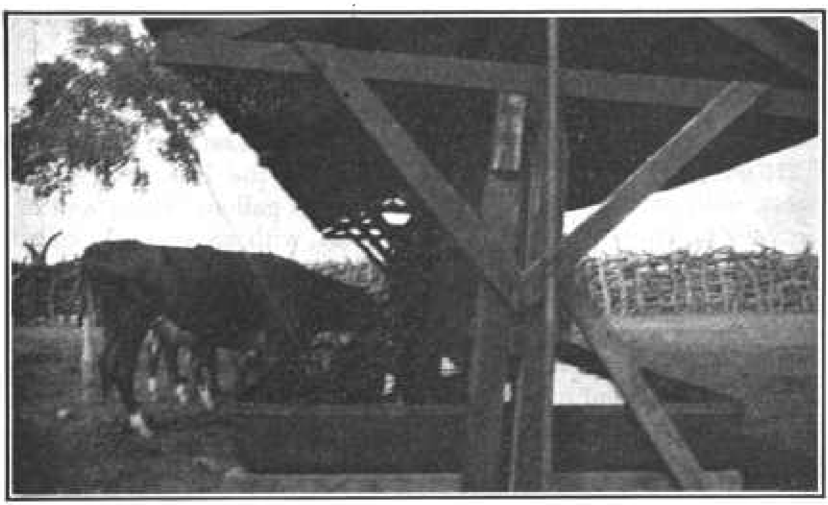

FIG. 3.—An unusually well-equipped watering plant in Arizona. Troughs are of heavy steel and roof protects water from sun. Water is raised from well several hundred feet deep by steam pump. Coconino National Forest.

heavy plank foundation from the top and allow it to sink as the work progresses. If properly laid, the walls will be perfectly safe against caving, moving sand will be effectively shut out, and the wall can be carried down to almost any depth. An open well has this objection, however, that unless the curbing is carefully laid and the top securely closed small animals get into the water and render it unfit for use for anything else than stock. The curbing should be carried up at least 2 feet above the ground, and the lid should never be left off. Where the water supply is rather limited an open well has the advantage that after reaching bedrock a "sump" or chamber can be excavated in which water can accumulate when the mill or pump is not working, thus considerably increasing the capacity of the well.

Deep wells and windmills.—Throughout the Texas Panhandle region the watering of stock from deep wells has been worked out almost to an exact science. Water is found in practically unlimited quantities at depths of from 150 to 300 feet, though there is little on the surface. When the entire region was one great cattle range it was considered most satisfactory to have a well at the intersection of every four sections, in order that stock would not have to travel over 2 miles in any direction to reach water. Finished wells such as those in Texas cost from $350 to $500 and upward, according to depth. A steel or wooden windmill complete, with pipe, cylinder, etc., and ready for use, costs from $150 to $300. Wooden towers cost from $30 to $60. The average Texas well complete, with mill, tower, troughs, etc., represents an investment of about $1,000. Under ordinary weather conditions such a well, in connection with a suitable reservoir for storing the water against a calm season, can easily supply between 350 and 500 cattle each day.

When such an outfit is well taken care of, repairs are not heavy. If the cylinder is placed below the surface of the water (as it should be) the valves need not be renewed more than once every 6 months unless an unusual amount of sand is raised. It is a very severe storm that does a windmill any damage, provided the weights are properly adjusted so as to meet sudden squalls. The life of a good windmill is reasonably long when it is given the proper care. The adherence to a few simple rules will often go a long way toward prolonging the life of a mill and avoiding costly breakdowns. When a mill is first assembled, and before it is put to use, every nut on it from one end to the other should be tightened with a wrench. After that, every bolt head should be riveted with a rivetting hammer, so that the nut will not work off under any circumstances. It is far cheaper in the end to cut off a bolt with a cold chisel and replace it with a new one, if such a thing seems necessary, than to neglect to do so, for nine-tenths of the breakdowns that occur when windmills are left to themselves are due to the nuts dropping off. At regular intervals, at least once each week, a windmill should be gone over carefully to see that every bolt and nut is tight. Parts which need it should be oiled. Windmills looked after in this way will seldom need expensive repairs.

Windmills are also used for raising water from deep canyons in which there are streams or springs. In some cases the mill is set back from the edge of the canyon and the power carried to the pump-rod by a "triangle." Several such plants are in operation in Arizona and New Mexico, raising the water from canyons from 100 to 300 feet deep with entire success. Any other pumping power, of course, can be used in the same way.

Other means of raising water.—While the windmill is the main dependence of stockmen for raising water, improvements in gasoline and oil engines have brought them into wide use, especially as auxiliary to the wind engine. No matter how great the reservoir capacity, long periods of calm are likely to occur during which the storage supply of water is exhausted. To meet such emergencies, gas engines mounted on wheels or wagons, so that they can be moved from one well to another, have been used with great success. The cost of a 2-horsepower gasoline engine is about $125 and a 3-horsepower $175 and up. Actual horsepower is also used for pumping purposes where the well is close to a camp or ranch. With either a sweep attachment or an ordinary treadmill, horses or burros useless for ordinary work can be utilized.

RESERVOIRS FOR PUMPING PLANTS.

No well is complete without a reservoir with a capacity large enough to carry the stock dependent upon it over a long calm spell. In the Panhandle country the common type of dirt reservoir is the one most used.

If possible the well should be located at a spot somewhat higher than the reservoir in order to give the water the necessary fall. Excavations for watering from 300 to 500 cattle are usually about 50 feet wide, 100 feet long, and about 3 feet deep. The walls can be built up with the dirt from the excavation, so as to give the entire reservoir an average depth of about 5 feet. Such a reservoir will hold approximately 200,000 gallons of water, enough to supply the number of cattle mentioned for several days, with due allowance for leakage and evaporation.

The cost of a reservoir of the dimensions given should not exceed $100, with ordinary wages for men and teams. When the work can be done by the stockman's employees and teams in the course of their ordinary work, the expense will be even less. The long, narrow type of excavation gives the minimum of haulage for the dirt, and the teams can be worked back and forth across the hole, thus avoiding loss of time in loading. Where there are no rocks to handle, two teams and several slip scrapers, or fresno scrapers, can get the earth out of the hole and into the banks very quickly

When the soil is of such a kind that it will not hold water readily, reservoirs are often lined with coatings of heavy crude oil or coal tar to make them water-tight. The entire surface of the tank is first rolled until it is fairly firm and solid, and is then gone over with a rake until the soil is loosened up to a depth of about an inch. The coating material, not boiling hot but warmed sufficiently to make it flow readily, is then spread by means of an ordinary broom or sprink-

ling pot until every part of the surface is covered. To cover a reservoir 50 feet wide, 100 feet long, and 4 feet deep, requires approximately 8 barrels of tar. If placed on the soil at boiling temperature the tar covering is likely to crack in cold weather. Stock should not be allowed to enter the reservoir after it is lined, because they are likely to cut the bottom with their feet. The cost is not heavy, and where clay can not be obtained and the slope is enough to permit troughs to be erected, it is in some ways the most satisfactory method of watering stock without danger of the water becoming foul.

Cement reservoirs.—Where windmills are used for stock watering purposes cement reservoirs to hold the water pumped by the mills have been very successful. Their usual size is 30 by 20 feet and from 4 to 6 feet high, holding approximately 20,000 gallons of water, and watering 200 head of cattle for a period of from 8 to 10 days. The walls and bottom should be from 5 to 6 inches thick and reinforced with wires, especially about the corners. Barbed wire is excellent for reinforcement. Where there is danger of the water freezing solid, the reservoir should be built with a decided slope to the inner walls. The slope can be obtained by making the walls 8 or 10 inches thick at the bottom and gradually narrowing them to 4 inches at the top. This will resist the pressure from the expanding ice, which otherwise might crack the walls.

The usual 1, 2, 3 mixture is probably the best for such a reservoir, although a mixture of 1, 3, 5 has sometimes been used successfully. The somewhat cheaper cost of the latter, however, scarcely justifies the possible loss in efficiency where the work is designed to be permanent.

Under ordinary conditions a reservoir of the size mentioned can be built at a cost of something like $100. This varies, of course, with the cost of materials and labor.

Troughs at reservoirs.—The use of troughs at reservoirs avoids to a certain extent the necessity of cutting ice in the winter, since the water can be drawn from beneath the ice in the reservoir, provided the troughs and float valve are kept open. Where stock use a reservoir directly, many owners prefer to have a string of troughs between each of the wells, the overflow from the last trough going into the reservoir. In winter, stock will drink the comparatively warm well water in preference to that from the reservoir and fare better on it. Where there is a string of five or six 10-foot troughs, and the mill makes an occasional turn, the water will not freeze in the first two or three troughs unless the temperature gets very low. Even then the animals can easily break the ice with their noses, a thing they very quickly learn to do.

STOCK WATER FROM MINING TUNNELS.

On several National Forests use has been made of the waste water from mining tunnels, especially those abandoned by their owners. Few tunnels run into the side of a mountain without striking a flow of water. If the mine is not being actively operated, and the owners are willing, the water running from the tunnel may be piped some distance to troughs, or a reservoir may be built. Frequently the tunnel itself may be used as a reservoir by closing the entrance with cement work and placing an outlet pipe some distance above the floor. By the use of a float valve, water can be drawn off at the troughs as needed. If the winters are cold enough to freeze the water and burst the pipe, it should be buried below the surface of the ground.

TROUGHS.

The kind of trough or other receptacle for holding water derived from wells and springs will depend very largely upon the character of the surroundings. Manifestly, it is necessary to utilize whatever material is in the immediate vicinity of the watering place, even though it may not work for either permanence or appearance. The feature of permanence should not be lost sight of, however, if it can be obtained without too great a sacrifice of economy.

Log troughs.—Hewed logs are and probably for a long time will continue to be by far the most common material for the construction of troughs. The fact that the trough can be constructed with the tools commonly at hand, and the low cost for renewals and repairs, are points which make for their use. The cost of a log trough depends to a great extent upon the skill and energy of the workmen. With labor at $2.50 per day, the cost of several 16-foot troughs hewed from yellow pine on an Arizona Forest was $7.50 each, which is rather high for this class of work. On an Oregon Forest the cost of log troughs is estimated at 20 cents per cubic foot of opening. On a Nevada Forest the cost is estimated at 14 cents per cubic foot of opening. On the Wallowa National Forest in Oregon the cost was from 21 to 26 cents per cubic foot for tamarack and 35 cents for yellow pine. Troughs may be hewed with an ax or burned out with fire, or both, as seems best. Where one man is making several troughs time may be saved by using fire, but otherwise it is likely to effect no material saving. Yellow pine burns more readily and hews somewhat harder than most other trees.

Aspen, yellow pine, spruce, and lodgepole pine are all used for troughs. In two cases, one in Utah and the other in Arizona, a string of yellow pine troughs is still in use after nearly 30 years' service.

Plank troughs.—Next to the log trough, the plank trough is the form most common on the National Forests. A plank trough is much shorter lived than a log trough and is likely to leak whenever

the water is out of it for a few days. The use of material more than 2 inches thick does not add much to its life. Painting the trough both inside and outside is always advisable. Two coats of lead paint or very thin pine tar not only preserves the wood but makes the trough less likely to leak after being left without water. The framing of such troughs should be carefully mortised together and braced with iron rods at both top and bottom. Where it is more than 6 feet long there should also be a brace in the middle. A string of plank sheep-watering troughs on a National Forest, built of 2-inch plank, 12 feet long, 12 inches deep, and 12 inches wide, holding about 90 gallons each, cost $4 per trough. On another Forest the average cost of plank troughs, built of 2-inch material, from 12 to 16 feet long, was approximately $10 each. This includes material and labor. The lumber used was unfinished, and the troughs were not painted. The cost of a trough may be greatly increased by using the higher grades of material. Clear, finished 2-inch plank is expensive anywhere, and its value for troughs is hardly great enough to warrant its use in place of the rough material of lower grades. Knots should be painted over with a heavy coat of lead paint or tar and then covered on both sides with pieces of tin. A knot thus reinforced will remain in place as long as the tin does, and will seldom leak. When either log or plank troughs begin to leak they may be temporarily repaired by throwing a few shovelfuls of earth into them. Strips of cloth forced into the open seams with a knife or sharpened stick will also remedy a great many leaky places.

Other forms of wooden troughs.—Another type of wooden trough is constructed of long, narrow staves bound together with steel rods. These troughs are half round in shape, and the rods pass through wooden cross pieces laid upon the top of the trough. By means of nuts at each end the rods can be tightened up as required. These are a little more expensive than the ordinary plank trough, and are made either of pine or redwood and in various lengths from 8 to 16 feet. As with the plank trough, the main objection to them is the shrinking whenever the water is drawn out or even lowered for any length of time.

Troughs are often made of planks put together with tongue and groove material in order to make them wider than single plank. These are built somewhat in the style of the ordinary water flume, and are held together by wooden frames of 4-inch timbers mortised and tenoned into each other and tightened by means of wooden wedges. Not only do the seams of these troughs open when the trough is left unfilled for a short time, but the planks themselves warp and do not readily come back into place when pressure from the wedges is applied. Moreover, they are the most expensive kind of wooden trough.

Metal troughs.—Where moderate cost, extreme lightness of weight, length of service, and low cost of maintenance are desired, the common metal trough used by stockmen is superior to any other type. They can be procured either completely built or in sheets punched and ready for putting together. Their lasting qualities, of course, are excellent, and even if a hole is cut in one when ice is removed during the winter or from some other cause, repairs may be made cheaply and with the tools on hand at almost every stock ranch. Metal troughs are commonly half round in shape, stiffened with an iron or heavy wooden rim about the top, and braced at intervals of 2 or 3 feet with iron rods, the ends of the latter passing through a 3 or 4 inch brace on the top of the trough exactly as in a wooden trough of similar type. They are but little more expensive than the stave trough and last much longer. A number of such troughs on the Kern Forest, in California, made of No. 18 galvanized iron, each holding 300 gallons, cost approximately $20 each delivered at the nearest railroad station. The cost of hauling them to the watering places was comparatively low, and in most cases the trough, workmen, tools, etc., were all hauled in one wagon. Each of the troughs was 3 feet wide, 12 feet long, and 18 inches deep. Another lot of smaller troughs, each holding 135 gallons and built of No. 22 galvanized iron, cost about $17 each delivered at the watering places.

Oklahoma pools.—In recent years there has come into use a type of watering trough, or more properly reservoir, known as the Oklahoma pool. This is made of a circular wall of heavy galvanized iron, generally not over 2 feet high above ground, and for sheep not over 12 inches above ground. The circular wall is placed on edge in the ground in a narrow trench about 6 inches deep. A covering of about 3 or 4 inches of stiff clay, well tamped and puddled until it becomes water-tight, forms the bottom of the tank. Such a watering trough is easily placed in position. The material comes in long strips ready for fastening together at the ends with rivets. A stout iron rod runs about the top, making it firm and safe. Oklahoma pools can be made as large as necessary, and a great number of stock can be watered at the same time without undue crowding and fighting. If an animal gets into the tank, no harm is done, for the bottom is improved by the tramping and the sides are so low that stock can easily step over them. As a convenient storage reservoir and water tank Oklahoma pools are very satisfactory and cost less than the ordinary watering trough made of the same material.

Dirt reservoirs.—The small dirt reservoir used for drinking purposes is the most unsatisfactory kind of trough. There is an undue amount of waste through evaporation and leakage, while the water is always more or less fouled by the animals. The reservoir can not be cleaned by any ordinary means, and so grows worse with time. The type

should be used only when other kinds are not available except at prohibitive cost, and should be replaced by something better at the first opportunity.

Cement troughs.—Where the materials are readily available, and the cost of cement not prohibitive, concrete is the best material for watering troughs. If the concrete is mixed and the troughs built in the proper way, the watering place is practically indestructible. The great weight of such troughs prevents them from being moved or overturned by either animals or floods. They are not affected by decay, are easily cleaned, and the cost of upkeep is small. On the other hand, the location of a cement trough should be carefully considered, since it can not easily be moved if located in the wrong place. The walls, especially the corners, should be well reinforced with iron rods or barbed wire placed in the wet cement as the work progresses. To avoid injury by freezing, it is customary to give the inside of the trough a gradual slope by making the sides thicker at the bottom than at the top. Where lumber for the forms is not readily obtainable, earth may be scraped up into a mound and the form of the trough excavated, the walls of the excavation forming the outside of the trough. When finished and the form removed, the inner and outer surfaces of the trough should be washed with a mixture of pure cement put on with a broom or brush. This will close all small cracks or seams and give the work a finished appearance. The inlet and outlet pipes should be placed in the mixture where required as the work progresses. A collar placed about the center of these pipes will prevent leaks caused by the water following the pipe through the cement. The important thing in constructing a concrete trough is to use enough of the required materials, especially cement, and to obtain materials of the highest standard.

Trough capacity.—If there is a strong flow from a spring, troughs need not be of unusual size or number. When left to their own devices cattle seldom travel or feed in large bodies, and it is safe to assume that under ordinary range conditions more than a dozen head of cattle or horses will scarcely ever come to water in one bunch. Sheep, however, must all be watered at one time, and that class of stock requires a long string of troughs, each of comparatively small capacity, rather than a few deep and wide troughs as for cattle. In deciding the question of trough capacity points to consider are the following: Average water requirements of each class of stock, as given on page 2, and in the case of sheep the usual size of the bands and the flow of the spring.

Foundations for troughs.—The life of any form of wooden trough will be greatly prolonged by placing it on a foundation which will keep its bottom out of the mud and water. At the same time, the trough should be set low enough to permit the young animals to

drink from it. Cement or rock foundations are much better than short pieces of logs, and should always be used, even where some slight expense of time and labor is required to obtain the needed material. If rocks are used they should be laid in cement, if possible, and the foundation layer should be placed deep enough in the ground to avoid freezing and made sufficiently wide to prevent settling when the ground about the trough becomes saturated with water. Moreover, a log trough 12 to 16 feet long when filled with water has considerable weight, and a slight sinking of either end of the foundation would cause the trough to leak or to overflow, and may finally result in the whole trough turning over. Where sections of a log are used for the foundation, they should be cut from some old, burned, pitchy tree, which is resistant to decay. If the bottom of a trough is hewed flat and bound to the foundation by means of a mortise 4 or 5 inches deep, the tendency of the log to roll will be overcome much better than by simply setting the trough upon the foundation and holding it in place by blocks or wedges. The latter are sure to work out of place.

In the case of cement troughs great care should be taken to have the foundation firm and solid. Otherwise its great weight will cause it to settle and perhaps turn over.

Connections between troughs.—The success of the use of log troughs depends very largely upon the kind of connection between them when more than one is used. The ends of each trough should be carefully squared with a saw, and the troughs placed as close as possible to each other, end to end. An open notch cut in the end of each trough, as deep as necessary, holding a strip of sheet iron or tin is the best means of carrying water from one trough to another. It will be found far superior to an iron pipe, for it will not clog up with leaves or grass.

Drainage about troughs.—Every effort should be made to keep the ground about troughs as dry as possible. There is bound to be more or less slopping of water as the animals drink, and a certain amount of overflow due to stoppage of the pipes. Moreover, the constant wearing away of the ground about the trough forms holes in which rain and snow water collect. For this reason the ground about the trough where the stock stand to drink should be dug away to a depth of from 5 to 6 inches as far back from the troughs as advisable. Into this excavation logs should be laid corduroy fashion, or else a layer of loose rock placed "Telford style," as closely together as they can be wedged, and in a way to obtain a fairly smooth and level surface. If this is done, and the old dirt placed on top, the ground about the troughs will usually be solid and dry. The top layer of earth will have to be renewed occasionally, of course, to counteract the wear by the feet of the animals and the effect of the wind. One of the commonest sights on a poorly managed range is a string of watering troughs so high that only the old stock can water, and with a bog

hole in front of them through which the animals must wade to obtain a drink.

General suggestions regarding troughs.—Every trough more than 18 inches wide should have a strong bar or plank placed lengthwise along its center as a means of keeping stock from getting into it, and perhaps drowning. This is especially necessary in the case of the half-round type, with its smooth bottom. The plank should be at least 1½ or 2 inch stuff, which will stand the weight of an animal thrown upon it, and should be wired or bolted firmly to the crosspieces. Sometimes it is advisable to use the planks laid side by side, so that no animal can get all of its head below the cover, or else placed so that the opening on one side is only wide enough to allow the animal to get its head into the trough as far as the eyes.

Every watering trough should be carefully staked down. Stock, especially cattle, in fighting for water may often throw the trough out of line or tip it over unless it is securely fastened. This can be done by placing stout posts of some decay-resisting wood at each corner and along the sides. The posts can be wired to the crosspieces or fastened by other means.

The most satisfactory overflow or waste outlet is made by placing in the end of the trough at the proper water level a short piece of pipe with an elbow at each end. On the inside of the trough another short piece should be screwed into the elbow so as to carry the pipe down to within a short distance of the bottom. To the outer elbow of the pipe should be screwed another pipe long enough to carry the water to the ground and off to a considerable distance, in order to avoid a mudhole about the trough. The good point in this arrangement is in the fact that as the water enters the outlet pipe so far below its surface, little or no foreign matter is likely to enter the pipe and clog it. Care should, of course, be taken not to create a siphon. In the bottom of every trough should be a hole at least 2 inches in diameter from which dirt and other matter may be washed out. The hole is ordinarily closed with either a wooden or metal plug. In the case of wide watering troughs it is often a good plan to run a fence through the center of the trough parallel with its length. This will keep the animals from trying to cross over or fighting across the trough, and will enable timid animals, which ordinarily stand about waiting for the rest to leave, to drink with the others. Where the troughs are not wide enough to be divided, it is often a good plan to fence them so that the animals can water only from one side. This is especially desirable where the back of the trough rests against a hillside, when the stock if allowed to approach from that side would either carry dirt and other waste material into the troughs or else slip in themselves. The one objection to the fence is that old animals, especially cattle, are very likely to keep the younger animals from drinking as long as they can hold their ground.

USE OF CEMENT.

Cement enters into so many important parts of water and other improvement work that a few suggestions regarding its use are given here. For complete directions regarding cement the reader should consult Farmers' Bulletin 461, "The Use of Concrete on the Farm."

Six-inch thickness of wall will be sufficient for almost every purpose of water development. The following formula gives the amount of the various materials needed in the preparation of concrete:

Quantities of materials in 1 cubic foot of concrete.

Mixture, 1 (portion) cement, 2 sand, 4 stone or gravel:	
Cement (barrels)	0.058
Sand (cubic yards)	.0163
Stone or gravel (cubic yards)	.0326

For all ordinary cement construction the 1, 2, 4 proportions are sufficient. This means that to 1 shovel or other measure of cement take 2 of sand and 4 of gravel or broken rock. In figuring on such work, multiply the number of cubic feet in the proposed concrete structure by the above factors. This will give for the cement the number of barrels required, and for the sand and rock the number of cubic yards. To reduce the cement to sacks, multiply by 4, there being on an average 4 sacks of cement to a barrel. One sack of cement is enough for 1 cubic foot of construction work. Assuming that the work around some spring will total 20 cubic feet, the amount of material needed would be as follows:

Cement $20 \times 0.058 = 1.16$ barrels or 4.64 sacks.

Sand $20 \times 0.0163 = 0.3260$ cubic yard.

Stone or gravel $20 \times 0.0326 = 0.652$ cubic yard.

Or, roughly, 20 cubic feet of concrete will take $4\frac{2}{3}$ sacks cement, $\frac{1}{3}$ of a cubic yard of sand, and $\frac{2}{3}$ cubic yard of stone or gravel.

Broadly speaking, sand may be said to include all stone or grains that will pass through a wire screen with $\frac{1}{4}$-inch mesh. Sand so fine that it will pass through a 40-mesh screen is unsuitable for concrete work. A 40-mesh screen is one that contains 40 holes to the square inch of surface. Sand should be free from clay, loam, or vegetable matter. To test it in this respect, place about 4 inches of sand in a pint fruit jar, fill the jar with water to within an inch of the top, place the cap on, and shake vigorously. If there is more than half an inch of clay or loam on top of the sand when it settles, the material is not fit for use. Sand made up of grains of various sizes is better than sand of uniform size grains. A sharp angular grain is the best, and hence "wind-blown" sand is never satisfactory. Gravel, like sand, should be made up of pieces of different sizes. For water troughs, spring curbs, and the like it should range between the size that will not pass through a $\frac{1}{4}$-inch screen up to that which will

pass through a $1\frac{1}{2}$-inch ring. It should be free from foreign matter, clay, loam, or dust. To get the best results, the sand and gravel should be screened separately and then mixed.

The ordinary wet mixture requires about 5 gallons of water to a sack of cement. Where the amount of concrete is small, the water should be applied by means of a sprinkling pot. In all cases it should be applied slowly in order to avoid washing the cement from the mixing board.

To mix the different materials, spread the necessary amount of sand 4 or 6 inches deep over a mixing board or frame of suitable size and as nearly water-tight as possible. On top of the sand put the necessary amount of cement. Then, with one man on each side, begin at one end and slowly shovel the mass over. The material should be poured from the shovel with a swinging motion so as to thoroughly mix the two parts. On top of this mixture place the rock and gravel, and shovel it all over again. During this operation the water should be added. The more the materials are mixed, the better the cement will coat each bit of gravel or grain of sand, and the more satisfactory will be the result.

The mixture should not stand more than 30 minutes before being used. If by any accident this should happen, the mixture should be thrown away, since remixing it would not be safe. As the cement is placed in the forms it should be tamped down with an ordinary tamping instrument. When the water begins to rise on top of the work it is an indication that the packing has reached the proper point of solidity.

Cement work should be sheltered from the direct rays of the sun for 5 or 6 days after being set. During this time it should be kept wet, in order that the drying-out process shall be gradual. Sacks, burlap, hay, or straw will serve the purpose.

Forms may be built of either rough or planed lumber. Where the work is in the ground, the earth itself will ordinarily form the molds. Care should be taken to see that the form is so braced and backed that it will not bulge out of shape. Forms should be as water-tight as possible so that the liquid cement will not run through the cracks.

Concrete will not be injured by freezing after it is placed in the forms, provided no strain is put upon it until it has thoroughly thawed out and become set. A heavy covering of straw over fresh cement work will generally prevent freezing.

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